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THE NATIONAL IGNITION FACILITY AND ITS LASER TECHNOLOGY

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The National Ignition Facility (NIF) will produce the high energy-density conditions necessary to achieve fusion ignition and energy gain in the laboratory for the first time. The NIF is being designed as a major component of the United States Department of Energy's science-based stockpile stewardship and management program. The goal of this program is to ensure the safety and reliability of the nation's nuclear weapons stockpile in the impending era of a zero-threshold comprehensive test ban, and to provide for future national security through industrial competitiveness, fusion energy research, and scientific advances in a range of fields.

The NIF will house a laser system, consisting of 192 laser beams, capable of delivering 1.8 MJ at 500 TW of temporally, spectrally and spatially tailored light at 351 nm to millimeter scale capsules containing deuterium-tritium fusion fuel. The engineering design for this facility was begun almost three years ago. The conceptual design,[1] based on x-ray drive ignition requirements,[2] was completed in May 1994. The estimated cost of the baseline facility was approximately $1.1B with a project completion in 2002. The NIF advanced conceptual design, completed in February 1996, extended the baseline design to include user requests, including: convertibility to direct drive; higher shot rate; smaller spot size capability; advanced beam smoothing capability; and diffractive optics for experimental flexibility and associated wavelength agility.

The NIF Project is comprised of engineering and scientific staffs from participating U.S. inertial confinement fusion laboratories—Lawrence Livermore National Laboratory, Sandia National Laboratory, Los Alamos National Laboratory and the Laboratory for Laser Energetics at the University of Rochester. Currently, the Project has teamed with an array of industrial partners including the Ralph M. Parsons Company, A.C. Martin and Associates, Sverdrup Facilities, Inc., TRW, SAIC, Physics International, Northrup-Grumman, and a host of U.S. optics manufacturers. Full NIF funding of $61M this year by the U.S. Congress will allow the Project to complete preliminary design in the fall of 1996, maintaining the schedule set two years ago. Progress made by the NIF Project and it's supporting science and technology program, as well as the heightened importance of NIF's mission, is reflected in President Clinton's recent request to the Congress for full NIF funding of $191M in FY1997. If funded at this level next year, the Project will begin final engineering design, initiate site work, and prepare, bid and award construction contracts for the experimental buildings.

In order to reach the NIF cost and performance baselines, major advances in laser design and technology have been identified and are currently under development at Lawrence Livermore, Sandia, and Los Alamos National Laboratories.[3,4] Coordinated activities are ongoing in laboratories of the Commissariat a l'Energie Atomique in France for their similar-sized Laser MegaJoule (LMJ). The NIF design uses a four-pass laser architecture to achieve higher energy per unit cost compared to single-pass, master-oscillator power-amplifier systems. The low-energy input pulse (about 2 J) is amplified in four passes through full-aperture amplifier modules, which are separated by a spatial filter to minimize nonlinear self-focusing. The laser gain medium is neodymium-doped, phosphate-glass slabs having a 40-cm square clear aperture pumped by large flashlamps (4.3 cm bore x 180 cm arc length) now under test. The flashlamps are driven by a highly integrated power conditioning system, which is capable of delivering over 300 MJ of electrical energy from approximately 200 modules. Sandia National Laboratory is leading development of the NIF pulse power. The laser architecture requires an optical switch that deflects the beam out of the laser cavity after the fourth pass. For this purpose, a large aperture plasma-electrode Pockels cell is located inside the laser cavity to cause 90° polarization rotation. Additional gain of the laser is provided by the booster amplifier both before the beam is injected into the laser cavity and after it has exited. The booster amplifier reduces the laser fluence on the polarizer to prevent optical damage. At nominal performance, the laser energy of each beamline will be approximately 16 kJ at 1 μm. The laser beam is frequency converted from 1053 to 351 nm wavelength using a pair of KDP crystals (one of which is deuterated) at the 10 m diameter vacuum target chamber. The beam is focused by a lens and passed through a phase plate (to control beam distribution on target) and through a debris shield to protect the output optics against target debris. Progress will be reported in Beamlet which is a scientific prototype beamline to test the NIF architecture and operating parameters.[5]

Laser component developments to enable NIF to meet its performance, cost, and schedule requirements are in the second year of a four-year development program (1995-98).[3] Some of the specialized laser components include monolithic ring fiber oscillators based on diode-pumped $Yb:SiO_2$; ultra-stable diode-pumped regenerative amplifiers, multisegment power amplifiers segmented into 4 high by 2 wide by 1-slab-long modules; multisegment plasma electrode Pockels cells; and diffractive optics to provide special functions. The optics development program is highly coordinated with industry in order to provide the new production techniques and facilities to produce the 9000 full-sized optics of NIF at the required cost and schedule. The cost of these optics must be reduced by 2-4 from the cost of Beamlet optics. Some specific developments include continuous melting of laser glass, rapid growth of KDP conversion crystals, and deterministic finishing methods. Particularly important is the use of power spectral density specifications to establish the requirements and to guide optics finishing development.

Presuming success of the NIF and associated ICF ignition campaigns, rep-rated ICF laser systems are of long term interest for defense and energy applications.

Brief comments will be made on our very limited activities in this area and how those activities are related to the NIF development.

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